

Production of Low Sulfur Fuel Oils From Utah Coals

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Hydrogenation is one of the potential methods of producing fuel oil from coal. Coal can be hydrogenated to fuel oil in the form of a paste¹, in ebulating bed² reactors, fixed beds³ and fluid bed⁴ reactor systems. In the present investigation, coal was hydrogenated in batch and dilute phase systems to produce oil. The coal oil was desulfurized in fixed and ebulating bed reactor systems to produce low sulfur fuel oils. The economics of producing fuel oils with 0.5 and 0.25 percent sulfur are presented in this communication.

Experimental

Coal was hydrogenated in batch and semicontinuous⁴ systems using Zinc Chloride as catalyst. The coal oil was desulfurized in fixed⁵ and ebulating bed⁶ reactor systems using a pelleted catalyst containing sulfides of nickel and tungsten supported on alumina. Product evaluations were done by standard methods.

Results and Discussion

The product distributions obtained in the batch work are given in Table I. Hydrogenation was carried out at a temperature of 500°C, initial hydrogen pressure of 2000 psi and reaction times up to 90 minutes. The results show that at a coal conversion of about 80 percent, the ratio of oil to gas yields will be about three and 23 percent of the coal sulfur will show up with oil. The data given in Table II indicate that the sulfur content of the oil remains almost same at different coal conversion levels. The sulfur content of the oil, probably, depends upon the organic sulfur content of the coal. The data given in Tables I and II were obtained from a coal containing about 0.6 to 0.7 percent organic sulfur.

The properties of the oil obtained in the semicontinuous dilute phase hydrogenation system⁴ are given in Table III. These oils were prepared from a coal containing about 2.5 percent total sulfur. The data show that the whole oil can be directly used as a fuel oil in places where one percent sulfur is tolerated. A 0.5 percent sulfur oil can be produced by desulfurization of either whole oil or the +300°C fraction. If a fuel oil of less than 0.5 percent sulfur is desired, the whole oil may have to be desulfurized.

The whole oil and +300°C fraction were desulfurized in bench scale fixed and ebulating bed reactor systems and the product distributions obtained are shown in Figures 1 and 2. The data show that fuel oils containing about 0.2 percent sulfur can be made by desulfurization of either the whole oil or the +300°C fraction. As the sulfur content of the product oil decreases, there will be an increase in the yields of low boiling oil, gas and coke. A comparison of the data indicates that the fixed bed system produces more gas and coke when compared to the ebulating bed system irrespective of the type of feed oil used.

A conceptual material balance of a refinery producing 100,000 BBL/day of fuel oil from coal was calculated (Table IV) based on the bench scale data obtained by the authors and the published data available. In this projection, a coal containing

7.5 percent moisture, 10 percent ash and about 2.5 percent total sulfur is used as the feed. The hydrogenation can be carried out in any type of reactor system in the temperature range of 500° - 550°C and a pressure range of 2000-3000 psi. The process conditions will be optimized for a coal conversion of about 80 percent. The hydrocarbon gases produced in the process will be used for making process hydrogen. The residual char will be used as a fuel. Based on the conceptual data, a preliminary economic evaluation of the process for making fuel oils of 0.50 and 0.25 percent sulfur was made (Table V). The calculations were based on approximate energy and material balances and estimated equipment costs. The data indicate that fuel oils can be produced from coal by hydrogenation at a manufacturing cost of about 5-6 dollars per barrel. The data (Figure 3) also show that the cost of reducing the sulfur content of fuel oil from 0.5 to 0.25 percent will be about 30-40 cents per barrel.

Acknowledgment

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Literature Cited

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Table I. Sulfur Distribution In Products

Sulfur Content of Coal: 1.31%

Coal Conversion, Wt. %	Product Yield, Wt. %			Sulfur Distribution, Wt. %		
	Oil	Gas	Char	Oil	Gas	Char
41	36	5	59	16	9	75
52	43	9	48	18	10	72
61	51	10	39	20	13	67
73	57	16	27	22	16	62
81	61	20	19	23	17	60

Table II. Sulfur Distribution in Oil

Coal Conversion, Wt. %	Sulfur Content of Oil, Wt. %
41	0.53
52	0.54
61	0.52
73	0.51
81	0.52

Table III. Analysis of Coal Oil and Its Fractions
(Sulfur Content of Coal = 2.5%)

	Whole Oil	-300°C Fraction	+300°C Fraction
Distribution, Vol. %	100.0	42.0	58.0
Sulfur, Wt. %	1.01	0.49	1.53
Nitrogen, Wt. %	1.22	0.65	1.31
Oxygen, Wt. %	5.65	4.54	6.57
H/C (Atomic)	1.09	1.25	0.96
Asphaltene, Vol. %	26.5	10.5	39.6

Table IV. Material Balance
Capacity: 100,000 BBL/Day of Fuel Oil

Sulfur Content of Fuel Oil, Wt. %

0.50

0.25

Raw Materials

Coal, Tons	39,500	43,500
Hydrogen, MM SCF	1,073	1,275
Catalyst, Tons	732	800

Products

C ₁ - C ₄ Gases, MM SCF	271	317
Naphtha, BBL	36,280	49,000
Fuel Oil, BBL	100,000	100,000
Char, Tons	8,052	8,800
Sulfur, Tons	175	175
Ammonia, Tons	350	350
Water, MM Gallons	1.1	1.1

Table V. Economic Summary (MM\$)
Capacity: 100,000 BBL/Day of Fuel Oil

Sulfur Content, Wt. %	0.50	0.25
Fixed Capital	312	344
Working Capital	31	34
<u>Total Revenue</u>		
Fuel Oil Price:		
\$5/BBL	238	261
\$6/BBL	271	294
\$7/BBL	304	327
Total Operating Cost	194	224
<u>Rate of Return %</u>		
Fuel Oil Price:		
\$5/BBL	6.9	5.4
\$6/BBL	12.2	10.2
\$7/BBL	17.5	15.0

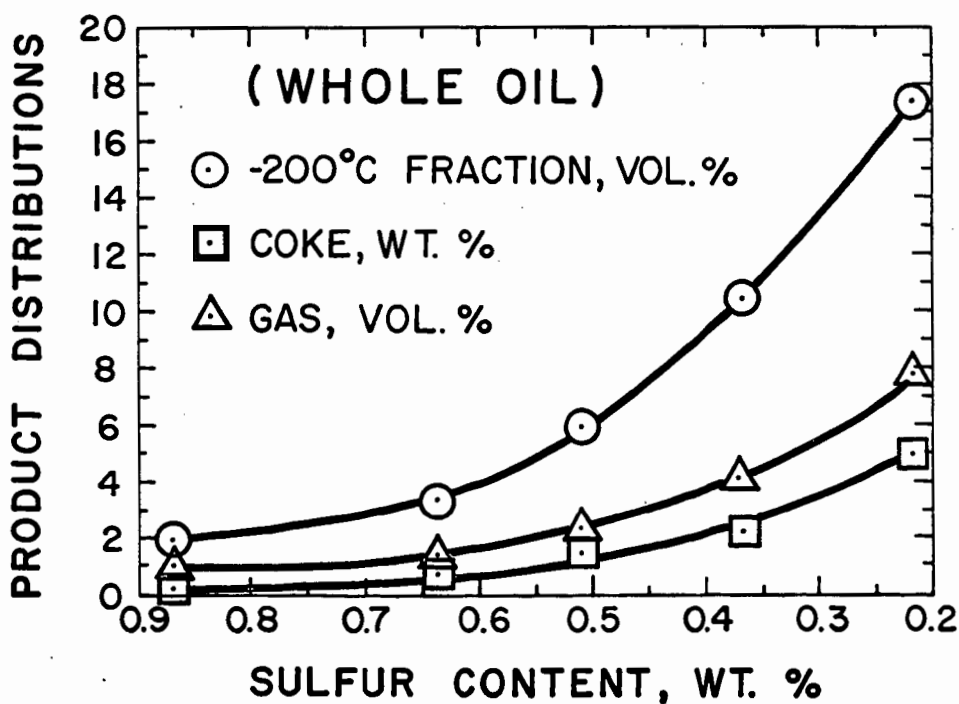
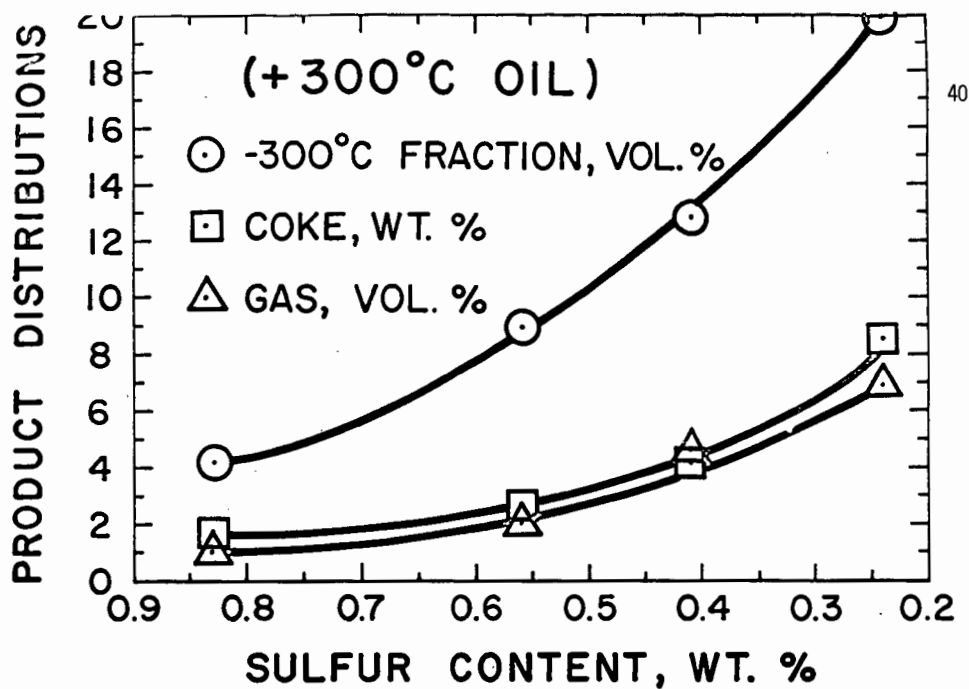


FIGURE 1. INFLUENCE OF DESULFURIZATION ON PRODUCT DISTRIBUTION (FIXED BED)

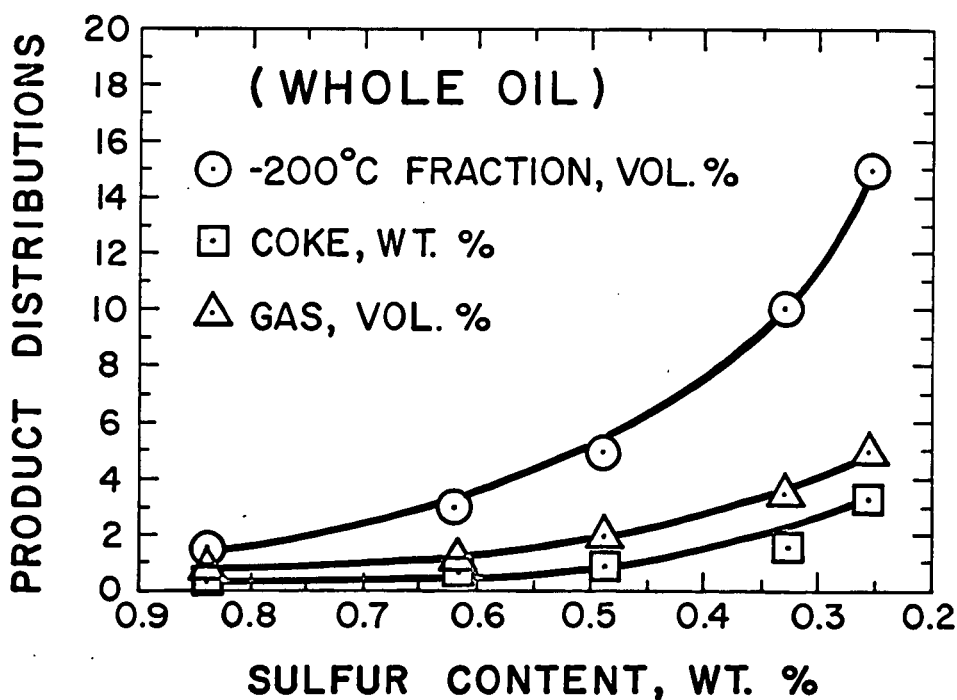
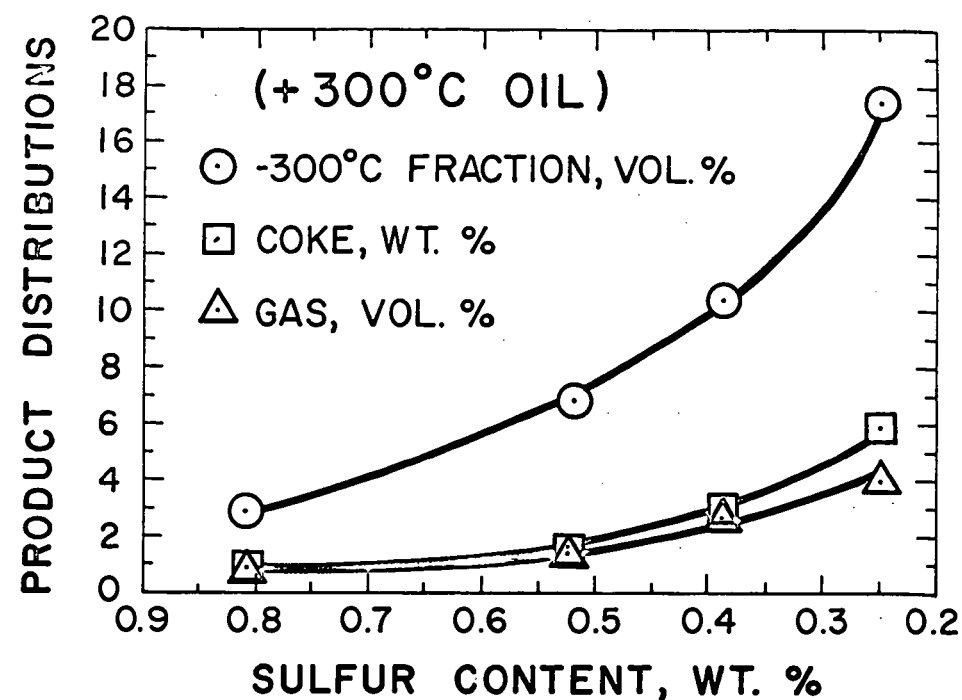


FIGURE 2. INFLUENCE OF DESULFURIZATION ON PRODUCT DISTRIBUTION (EBULATING BED)

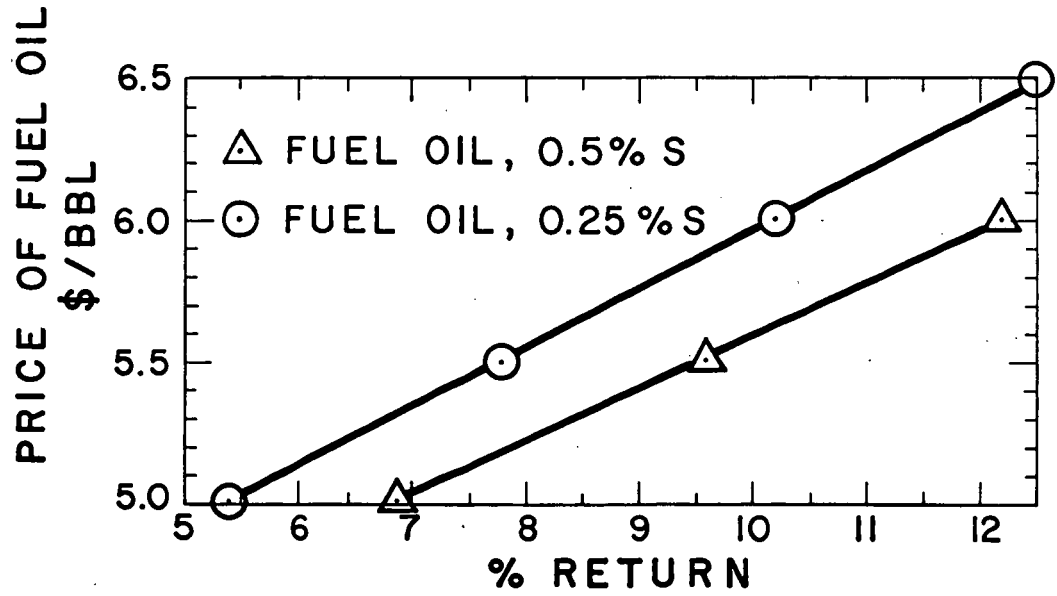
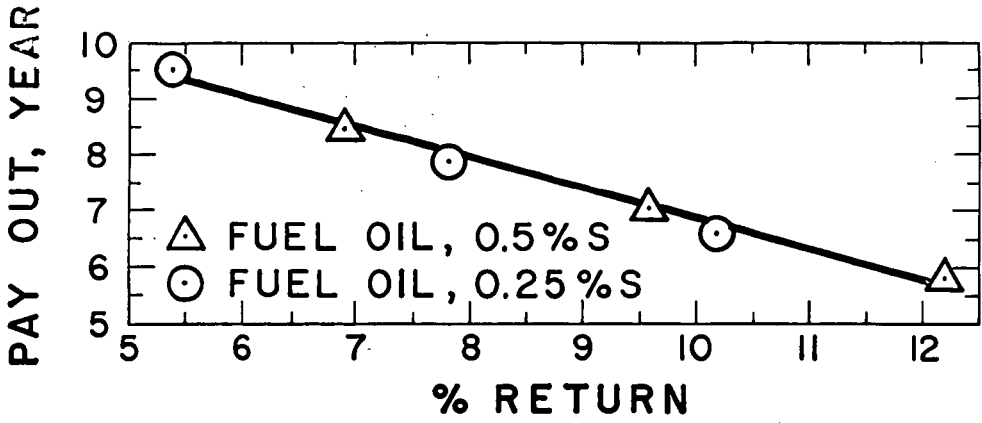


FIGURE 3. VARIATION OF RETURN AND PAYOUT TIME WITH FUEL OIL PRICE